Institution: University of Stirling

Unit of Assessment: B7 Earth Systems and Environmental Sciences

Title of case study: Environmental Radioactivity: Regulation and Protection

1. Summary of the impact

The science conducted in environmental radioactivity and radioecology ranges from the development and deployment of detection systems to the characterisation and implementation of radiological risk assessment tools. This has led to impacts in international standards, regulation development and regulation enforcement, including: advising the Scottish Environment Protection Agency (SEPA) on hot particle hazard, risk, detection and recovery; developing the framework for environmental protection through the International Commission on Radiological Protection; developing standard specifications for the manufacture of environmental monitoring equipment for the International Electrotechnical Commission; and providing training courses through the International Atomic Energy Agency.

2. Underpinning research

The Environmental Radioactivity Laboratory (ERL) at the University of Stirling is led by Dr David Copplestone and Professor Andrew Tyler. At the radioecology end of the ERL's research spectrum, we have developed radiological risk assessment methods for humans and wildlife, and assessed the impacts of radionuclides released during radioactive waste management and disposal, reprocessing, power generation and nuclear accidents. Our current research in this area is focused on understanding the ecological effects of ionising radiation, and how ecological systems adapt to the environmental stress caused by such exposure. Models developed by Copplestone of radionuclide transfer and behaviour have been used to improve radiological risk assessments. We have also applied genetic and molecular techniques to better understand radiological impacts on wildlife. We continue to assist the Environment Agency in the development of their approach to wildlife risk assessment from ionising radiation. Our research into radionuclide transfer parameters to, and on the biological effects of ionising radiation on, wildlife is contributing to the development of international databases (www.wildlifetransferdatabase.org and www.frederica-online.org respectively). The scientific understanding derived from his research is currently being used in the development of the International Commission for Radiological Protection's (ICRP), recommendations for environmental protection (he is a member of the ICRP's Committee 5).

At the physical end of environmental radioactivity research, we specialise in laboratory, in-situ and mobile gamma spectrometry, environmental dosimetry and the characterisation of radioactive hot particles and developed the ISO17025 accredited ERL to demonstrate system quality and traceability. The development of real time in-situ and mobile gamma detector systems (exploiting new crystal technologies and configurations) offer immediate benefits to surveys of contaminated land, site characterisation and determining dose rates but is hindered by variations in the vertical activity distribution leading to significant loss of measurement accuracy. This research exploits characteristics of scattered photon radiation using novel spectral algorithms, driven by empirical and Monte Carlo approaches, to yield information on the spatial (including depth) distribution of specific radionuclides in the environment. Importantly, this approach provides the way forward for more accurate in-situ estimation of environmental radioactivity concentrations to: 1) support baseline surveys for environmental radioactivity; 2) enable the detection of hot particles; and 3) provide accurate real-time contaminated land assessment. The ERL undertook the first in-situ radiometric survey at a national scale to estimate the background radionuclide concentrations and contributions to external gamma dose rate for Environment Agency, Scottish and Northern Ireland Funding for Environmental Research, Food Standards Agency and Department for Environment, Food and Rural Affairs. By exploiting airborne remote sensing techniques we provided maps of the distribution of radionuclides in estuarine environments for better dose characterisation of people and wildlife. This was expanded further to establish the dose rates to critical groups within the Ribble Estuary in support of the Environment Agency's dose assessments, where it was demonstrated that the monitoring of Beta and Gamma dose rates for regulatory purposes were inadequate. This resulted in revisions in the statutory monitoring programmes taking account of our recommendations on correct instrument deployment, use and data processing. We have also been working on Radium-226

particle dosimetry through skin contact and simulated stomach digestion to all human age groups, underpinning the Scottish Environment Protection Agency's regulatory activities at Dalgety Bay (UK) and the implementation of the contaminated land regulations.

3. References to the research (Stirling staff in bold)

Key publications:

1. **Tyler, A.N**., Dale, P., **Copplestone, D**., Bradley, S., Ewen., H., McGuire, C. Scott, E..M. (2013). The Radium Legacy: Contaminated land and the committed effective dose from the ingestion of radium contaminated materials. *Environment International.* 59, 449-455.
2. **Copplestone, D**. (2012). Application of radiological protection measures to meet different environmental protection criteria. *Annals of the ICRP.* 41; 263-274.
3. **Tyler, A.N.,** Scott, E.M., Dale, P., Elliott, A.T., Wilkins, B. T., Boddy, K., Toole, J. Cartwright, P. (2010). Reconstructing the abundance of Dounreay particles on an adjacent public beach in Northern Scotland. *Science of the Total Environment.* 408, 4495
4. Howard, B.J., Beresford, N.A., Andersson, P., Brown J.E., **Copplestone D.,** Beaugelin-Seiller, K., Garnier-Laplace, J., Howe, P.D., Oughton, D., and Whitehouse, P. (2010). Protection of the environment from ionising radiation in a regulatory context-an overview of the PROTECT coordinated action project. *Journal of Radiological Protection*. 30, 195-214
5. **Tyler, A.N**. & Copplestone D (2007). Preliminary results from the first national in situ gamma spectrometry survey of the United Kingdom, *Journal of Environmental Radioactivity*, 96 (1-3), pp. 94-102.
6. Rainey, M., **Tyler, A.N.,** Gilvear, D.J., Bryant, R., and McDonald, P., (2003). Mapping Estuarine Intertidal Sediment Size Fractions through Airborne Remote Sensing*. Remote Sensing of the Environment* . 86: 480
7. **Tyler, A.N.,** Sanderson, D.C.W. and Scott, E.M. (1996). Estimating and Accounting for ^{137}Cs Source Burial through *In-situ* Gamma Spectrometry in Salt Marsh Environments. *Journal of Environmental Radioactivity.* 33(3): 195-212.

Funding

1995-98	NERC (ARSF). Stirling led research using spectroradiometry field equipment and airborne remote sensing of the Ribble Estuary to characterise intertidal sediment grain size distribution and Sellafield radionuclide concentrations. NERC Scientific Services (£70k)
1995-05	3 PhDs funded by NERC, BNFL Sellafield Ltd and University of Stirling. Remote sensing and modelling of intertidal radionuclide bound sediments and flux in estuarine environments
2002-04	EA lead consortium of Government Departments and Agencies: National Soil and Herbage Pollution Survey: In-situ Gamma Spectrometry (£200k: £47k to Stirling).
2007-08	Geological Survey of Northern Ireland. Ground Reference Data Collection: Validation of the Tellus Airborne Gamma Spectrometry Survey of Northern Ireland. (£15k). Lead PI with the British Geological Survey
2008-09	EA. Dose reconstruction to critical groups in the Ribble Estuary. (£50k; £25k to Stirling).
2010-13	Sellafield Ltd. Statistical Advise on Radioactive Particle Monitoring, Stirling collaboration with University of Glasgow. (£15k to Stirling)
2011-12.	SEPA. Stirling led Dalgety Bay Headland Investigation, particle digestion, dose characterisation. (£80k)

2011-13	SEPA. Baseline characterisation around nuclear sites by Stirling: Torness and Chapelcross (£18k)
2012-13	SEPA. Development of a mobile monitoring gamma spectrometry system for contaminated land characterisation (Phase 1) (£12k).

4. Details of the impact

As an internationally leading expert on radiological protection of the environment, Copplestone has been appointed to Committee 5 (Environmental Protection) of the International Commission on Radiological Protection (ICRP). The ICRP helps to prevent cancer and other diseases and effects associated with exposure to ionising radiation and to protect the environment. The ICRP developed and maintains the International System of Radiological Protection used world-wide as the common basis for radiological protection standards, legislation, guidelines, programmes and practice. Copplestone drafted new recommendations on environmental protection which have been translated by the International Atomic Energy Agency into the International Basic Safety Standards.

Being extensively involved in the development of radiological risk assessment tools for wildlife, Copplestone is a technical expert for the International Atomic Energy Agency's (IAEA) technical cooperation projects for Eastern Europe (over the last three years), and has been invited to advise on environmental impact assessment from nuclear power plants to Malaysia from September 2012. Furthermore, for the last three years Copplestone has been involved jointly with the Centre for Ecology and Hydrology and Institut de Radioprotection et de Sûreté Nucléaire in France to provide training courses on radiological protection of the environment tools and techniques as part of a NERC funded knowledge exchange programme. This was extended in 2012 to two training courses in Australia at the request of the Australian uranium mining industry who are just introducing environmental protection into their assessment requirements.

Copplestone has also been instrumental in setting up international databases on the environmental transfer of radionuclides to wildlife (the Wildlife Transfer database) and the biological effects of ionising radiation on wildlife (FREDERICA). These databases are currently hosted online by Stirling and available for free to any interested parties and are being used in compilations of data such as the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) 2011 biological effects on non-human species review and the International Atomic Energy Agency's technical report series (in press) on radionuclide transfer to wildlife and the International Commission on Radiological Protection (ICRP) publication 114 on radionuclide transfer to the ICRPs reference animals and plants.

Copplestone continues to provide technical expert input to national and international committees (e.g. Oslo-Paris Convention for the North-East Atlantic on behalf of the Department of Energy & Climate Change and Defra; IAEA Action Plan on Environmental Protection on behalf of UK; cross government department review of the revision of (International and European) Basic Safety Standards for radiological protection on behalf of the Environment Agency and SEPA).

Recognised for the expertise in environmental gamma ray spectrometry and dosimetry, Tyler was appointed to Dounreay Particle Advisory Group to provide expert advice to Scottish Environment Protection Agency (SEPA) and the United Kingdom Atomic Energy Authority (now Dounreay Site Restoration Ltd) on the radioactive hot particle issue in 2000 (ending in 2009) - resulting in significant improvements in the on/offshore monitoring programme for particle abundance important in assessing the hazard and risk to human health. This was in response to a request to SEPA by the Secretary of State for Scotland and the work fed directly into SEPA's regulatory requirements within Dounreay's site licence. In 2009 he was appointed to the Particle Recovery Advisory Group (Dounreay), advising SEPA and Dounreay Site Restoration Ltd on the on/offshore particle recovery programme and strategy, resulting in 1248 particles being recovered offshore using Remotely Operated Vehicle technology. In 2011, Tyler was appointed to the Dalgety Bay Particle Advisory Group advising SEPA on the Ra-226 monitoring and hazard. Now recognised as one of the UK's experts on hot particles he has been working with Sellafield Ltd to provide advice on the statistical interpretation and monitoring strategies to be employed in relation to the hot particles on Cumbrian beaches to establish optimal monitoring strategies. The ERL is now well established and embedded within the SEPA's R&D framework, supporting key

regulatory activities and helping SEPA to check for regulatory escape. Our work has been critical in providing the evidence base for SEPA to interpret the UK's radioactively contaminated land regulations for enforcement work at Dalgety Bay.

In London 2008, as the UK expert Tyler was elected to convene the International Electrotechnical Commission (IEC) working Group (Nuclear Instrumentation Subcommittee 45B-Environmental Radiation Protection) and was project leader for the international standards on mobile monitoring (IEC 62438) and in-situ gamma spectrometry (IEC 61725) instrumentation (with meetings in Paris 2008, Yokohama 2009, Seattle 2010, Las Vegas 2011, Karlsruhe 2012, and Moscow 2013). This has resulted in IEC technical standards that all manufacturers adhere to in the construction, technical specification and environmental tollerances of equipment used for environmental radioactivity measurement, monitoring and dosimetry. In 2012 Tyler was invited to chair National Committee 2 of the British Standards Institute (BSI), reviewing ISO and IEC standards for Radiation Protection to establish their suitability for the UK and inclusion by the BSI.

5. Sources to corroborate the impact

Hot Particle: Expert advice on hot particle detection, recovery and the protection of humans

- Dounreay Particle Advisory Group (DPAG) reports: http://www.sepa.org.uk/radioactive_substances/decommissioning/dounreay/particles_advisory_group.aspx *www.sepa.org.uk/radioactive_substances/publications/dounreay_reports.aspx*
- Particle Recovery Advisory Group (Dounreay) (PRAG(D)): www.sepa.org.uk/radioactive_substances/decommissioning/dounreay/particles_advisory_group.aspx
- Dalgety Bay Particle Advisory Group (DBPAG) *www.sepa.org.uk/radioactive_substances/dalgety_bay/particles_advisory_group.aspx*
- Work supporting regulation enforcement at Dalgety Bay: http://www.sepa.org.uk/radioactive_substances/publications/dalgety_bay_reports.aspx

The International Electrotechnical Commission (IEC), Nuclear Instrumentation Subcommittee 45B. Convener of Working Group B5: leading and coordinating projects to prepare standards for environmental radiation protection purposes

- www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1360,25
- Example of an IEC standard that Tyler was project lead on: http://webstore.iec.ch/preview/info_iec62438{ed1.0}b.pdf

Doses to Biota: Generation of international databases for risk assessment and provision of expert advice and recommendations for regulation

- *Wildlife transfer database* - www.wildlifetransferdatabase.org and ICRP (2009) Environmental Protection: Transfer Parameters for Reference Animals and Plants ICRP Publication 114 Ann. ICRP 39 (6), Authors: P. Strand, N. Beresford, D. Copplestone, J. Godoy, L. Jianguo, R. Saxén, T. Yankovich, J. Brown
- *Radiation effects database* - www.frederica-online.org and UNSCEAR (2011) Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR 2011 Report to the General Assembly, with Scientific Annex.
- International Commission for Radiological Protection - www.icrp.org/icrp_group.asp?id=12
- International Atomic Energy Agency's *technical cooperation programme* - www.iaea.org
- *NERC KE project* - www.ceh.ac.uk/protect

Letters confirming the impacts of the ERL are also available from Environment Agency, UK, Australian Radiation Protection and Nuclear Safety Agency, International Electrotechnical Commission (IEC; France/US) and the Scottish Environment Protection Agency, UK